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TAKING INDICATOR DIAGRAMS OF HIGH PRESSURE GAS COMPRESSORS

/ The following is a translation of an article by L.F.Vereshchagin and B.P.Demyashkevich entitled "Inditserchaniye gazovogo kompressora vysokogo davleniya" (English version above) in Pribory i Tekhnika Eksperimenta (Instruments and Experimental Procedures),No.1,Moscow, Jan-Feb 1960,pages 118-122./

We give a description of a high pressure gas compressor and methods of obtaining indicator diagrams by means of three types of detectors. The designs of these detectors and their technique of operation are described. We give the indicator diagram obtained with an ionic glow discharge detector.

As a rule, gas compressors in which we succeed in achieving substantial pressures have multi-stages. The compression ratio of each stage in such a compressor does not exceed 6-7. Independent foreign firms manufacture a super-high pressure single-stage gas compressor. The firm "Amslep" in Switzerland manufactures a four-stage compressor with a hydraulic device and with automatic control. With an intake pressure of one kilo-atm , the compressor permits gas compression up to 4 kilo-atm. Sage and Lacey /1/ published the design of an experimental gas compressor, intended for study of thermodynamic properties of condensed liquids. This compressor permits compression of air from pressure 270 to 800 kilo-atm. Korndorf /2/ constructed a gas compressor for a pressure up to 5 kilo-atm. 1

Vereshchagin and Ivanov have constructed a single-stage gas compressor /4/ for a pressure up to 5 kilo-atm with a compression ratio of 100. Such a high compression ratio is caused by an extremely small idle volume, occupying 0.01 of the working volume, and a securely sealed compression chamber. The sealing of the piston in the compressor, in contrast with the sealing used in the majority of high pressure compressors, is realized by means of an elastic steel sleeve (section).

As is known, the actual compression cycle in a super-high pressure compressor is considerably more complex theoretically and the equation of state only approximately describes the real picture of the complex processes which take place in the cylinder of the super-high pressure gas compressor. In contrast with the theoretical indicator diagram, the intake line and the delivery line are not straight, which is caused by a variable pressure loss during the flow of gas through a channel, which is connected with a variation in gas velocity depending on the piston speed, vibration of the valves, vibration in the supply lines. The compression curve as well as the expansion curve deviate from the polytropic curves, which they characterize in the theoretical cycles; these deviations are caused by heat exchange between the gas and the cylinder walls. During intake the gas extracts heat from the heated cylinder walls; thus, initially compression occurs with heat supply, and consequently, with an index greater than the adiabatic index. In the compression process, the gas temperature increases, the temperature difference between the cylinder walls and the gas, by decreasing, becomes instantaneously equal to zero, viz. the process becomos instantaneously adiabatic. Then during the displacement of the piston, the gas begins to give off heat to the cylinder walls and the polytropic index changes sign.

The most complete representation of the processes occurring during the gas compression in a super-high pressure compressor gives an indicator diagram taken directly from the working compressor.

DESCRIPTION OF THE APPARATUS

The apparatus includes a single-stage compressor with a driving gear from an electric motor, equipment for precise measurement of the rod position, a high-pressure valve, a supply line, and compressing equipment. An overall view of the equipment is shown in Fig.1. We give a description in principal form of only the main part of the equipment - the head of the gas compressor and the measuring equipment.

During gas compression to high pressures, large loads act on the components of the compressor head. This fact led to the necessity of making the compression chamber in the form of a multi-layer vessel. The design of the head is given in Fig.2. A coupling sleeve is inserted inside the frame of the head 8 onto a sliding fitting. Into the coupling sleeve is inserted cone valve 3, the lower end of which rests on the sealing sleeve 4. Sleeve 4 rests on the frame of the lower seal 5. In the lower part of frame 5 is located a cascade of elastic steel sleeves 6, which prevent the escape of the gas from the admission chamber. The cascade sleeve is adjusted by nut 7. The cone valve in the upper part has a conical bore, to which a cone valve 2 is carefully reset, which valve moves in guide 1. The main components of the head are manufactured from steel alloys type Shkh 15, 40 Kh, 45 KhNMFA with adequate heat treatment. The components of the head are made to a high degree of precision and are finely machined. A precision pair- a piston -elastic sleeve-is reset to a highly polished surface and has a clearance of 0.03-0.04 mm at the diameter when mounted. Un this design, an elastic steel sleeve 4 of the Vereshchagin and Ivanov system /3/ is used as a seal of the moving piston.

OPERATION OF THE APPARATUS

Gas from a cylinder under a pressure of 50-80 atm enters along a supply line into the inlet system through an orifice in the frame of the head and fills up an annular space, formed by the frame of the lower seal and the slotting in the outer frame. The filling of the compression chamber begins at the moment when the reinforced part of the piston uncovers the orifice in the frame of the lower seal with its upper bead. The filling of the compression chamber will occur until the beaded edge of the piston, during its motion to the upper dead center, does not cover the intake orifice. As only the upper part of the rod enters into the elastic sleeve, the compression begins in the upper chamber, and also in the chamber formed by a reinforced part of the piston and the frame of the lower seal. Therefore the degree of pressure increase proportional to the piston displacement in each of the chambers will be unequal because of the different volumes, determined by the piston in the upper and lower chambers.

The geometrical relations of the components of the head are maintained in the lower chamber with a small degree of pressure increase. A decrease in the pressure difference between the chambers reduces the possibility of a leak from the upper chamber. The compressed gas flows through a pressure valve 2 into a pressure line then along a supply line through a pressure valve and enters a receiver. The operation of a compressor over the necessary pressure limits is guaranteed by an appropriate needle valve aperture. The friction surface is lubricated by means of Stauffer lubricating grease.

MEASURING APPARATUS

The pressure variation in the compressor cylinder as a function of the piston position is controlled by a detector. The detector was screwed into the compressor head and was connected through an opening to the upper part of the compression chamber (Fig.2). The studies were conducted by means of three types of detectors: 1) piezoelectric crystal, 2) induction detector , 3) normal glow discharge ionic detector /4/.

In this paper it is not necessary to describe in detail the design and technique of working with piezoelectric crystal detectors, because detectors of a similar nature are widely used in various measurements. The research detector was made from two plates of barium metatitanate (fig.3). The casing of rod 2 is screwed into the compressor head. Into the casing we carefully insert a ground rod 2, on which the diaphragm of the detector housing 3 rests. The rod is utilized to decrease the gas pressure on the diaphragm. Inside the detector ,on the spherical support, are found two plates prepared from barium metatitenate. The piezoelectric crystals were subjected to preliminary tightening so that the pressure on the plates was proportional to the variation in gas pressure on the diaphragm. The charge which originates on the surfaces of the plates due to compression moves across the inlet 4 into a d-c amplifier and then into a MPO-2 loop oscillograph. The detector was calibrated by means of a hydraulic compressor when mounted to the equipment onto the compressor.

Besides the piezoelectric crystal detector we used an induction detector; detectors of this type as well as the piezoelectric crystal type are widespread. The induction detector was mounted on the compressor head at the same place as the piezoelectric crystal. Fig.4 gives a diagram of the detector arrangement. The induction detector in assembly 1 is clamped by nut 2 to reducer 3. Through pellet 5 ,the movable part of the detector--rod 4 bears on diaphragm 6,inserted in the compression chamber.The deflection of the diaphragm during a process of gas compression is proportion to the pressure variation in the cylinder. Displacements of the diaphragm by the pellet are transmitted by the movable part of the induction detector; its signal is recorded by a loop oscillograph. The detector is calibrated together with the diaphragm against the equipment in the compressor.

For a more accurate study of the gas compression process in the compressor, we used a normal glow discharge electronic detector. This type of detector is very sensitive to a small displacement of a moving electron. Fig.5 presents the design of this detector. A stationary molybdenum electrode 2 is placed in the glass cylinder 1. The bottom of the cylinder is a metallic diaphragm of a special alloy. The pressure inside the cylinder, the magnitude of the discharge gap are determined so that a normal glow discharge arises between the electrodes. In this case the detector possesses maximum sensitivity. Diaphragm 3 is made from type Sh Kh-15 steel and is heat treated to great hardness. The diaphragm is secured to the head by a clamp nut 4 at the same places where the two previous detectors were situated. During its preparation we placed in the center of the diaphragm a rod, on which we placed a movable detector electrode. With a pressure variation in the compression chamber, the diaphragm is displaced and the distance between the detector electrodes changes. The detector signals move to a d-c amplifier and are recorded by a POB 14 oscillograph.

For the orientation of the indicator diagrams relative to the angle of rotation of the crankshaft, marks were drawn on the recording, corresponding in a definite way to the moving piston. Five points were chosen 54 deg apart. For this purpose, the sheave of a photocell was fixed onto the compressor. Each photocell had an individual socket in the sheave and an aperture through which a beam of light passed. In front of the sheave was a moving needle, connected to the crankgear of the compressor, alternately overlapping the aperture and causing the signal registered by the oscillograph.

Fig.6 presents the indicator diagram obtained by means of an ionic glow discharge detector. As was stated above, the compression in the upper chamber begins at the moment the rod penetrates the elastic sleeve. On the diagram this corresponds approximately to point 1. Starting at this moment the degree of the increase rises sharply. The components of the crankgear sustain large loads on this part.

During the displacement of the piston rod to the upper dead point (v.m.t.) ,large stress is applied to the pressure valve from the direction of the compression chamber. When the stress acting on the valve from the direction of the compression chamber exceeds somewhat the stress from the direction of the delivery line,- the valve is opened and the gas flows into the delivery system. The moment for opening the valve depends on the inlet pressure and the strength of the spring valve. On the diagram this corresponds approximately to point 2. During the dead point (v.m.t.) transition by the rod, the pressure in the compression chamber begins to decrease, and the valve closes under the action of the forces directed from the direction of the delivery line and the elastic force. On the diagram this corresponds to point 3. The amount of gas remaining in the compression chamber after the valve closes is determined by the idle volume and operating conditions of the valve. The residual gas expands until the apertures of the exhaust close (point 4). The area of the indicator diagram expresses , on a certain scale, the work expended in compressing the gas during a single working stroke.

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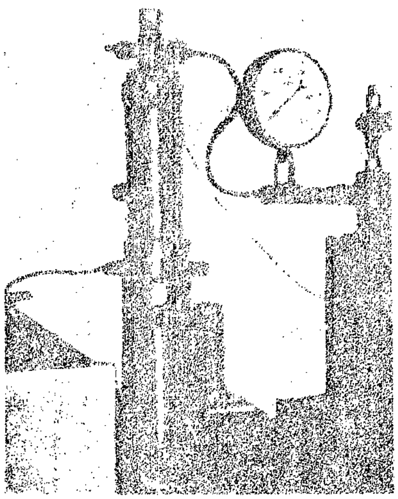


Fig. 1. Overall View
of the Equipment.

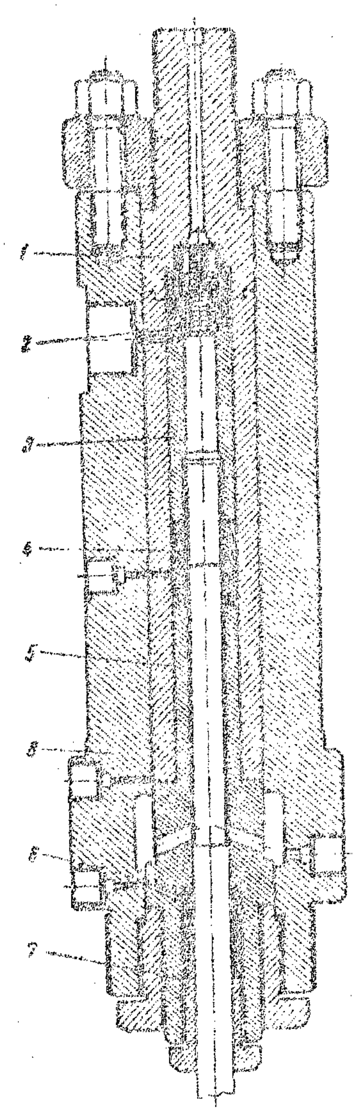
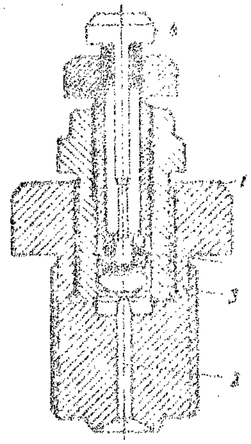


Fig. 2. Section of the Gas
Compressor Head.



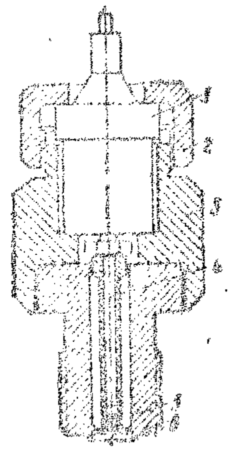


Fig. 3. Section of the Piezoelectric Detector.

Fig. 4. Assembled Induction Detector With Diaphragm.

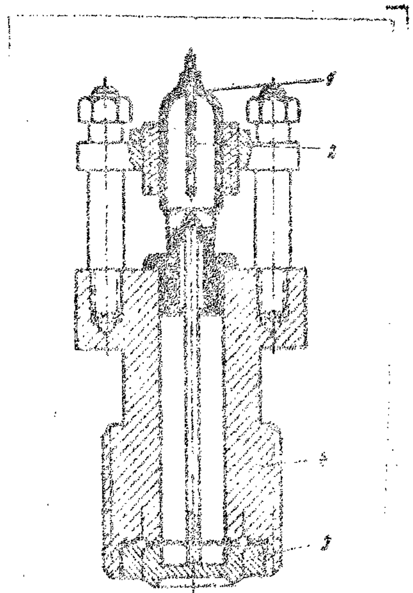


Fig. 5. Section of Ionic Detector With Diaphragm.

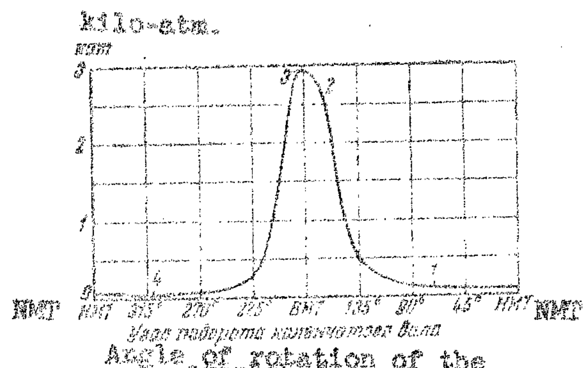


Fig. 6. Indicator Diagram

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